

ENGINE MANUFACTURERS MEET NEW ENERGY AND AIR QUALITY CHALLENGES

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Maritime Air Quality Technical Working Group

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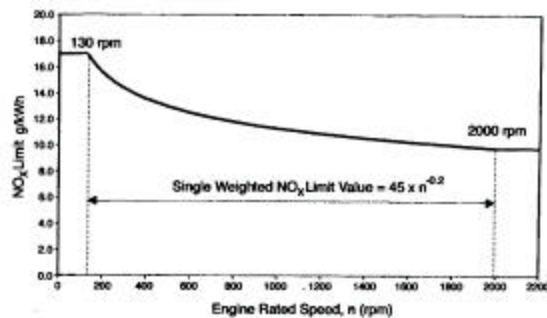


- ❑ Marine Emissions Legislation
- ❑ Medium Speed Engines
- ❑ Slow Speed Engines
- ❑ Energy Savings
- ❑ Alternative Fuels
- ❑ Conclusions and Recommendations

International Maritime Organization (IMO)



Marpol Annex VI NO_x Limits

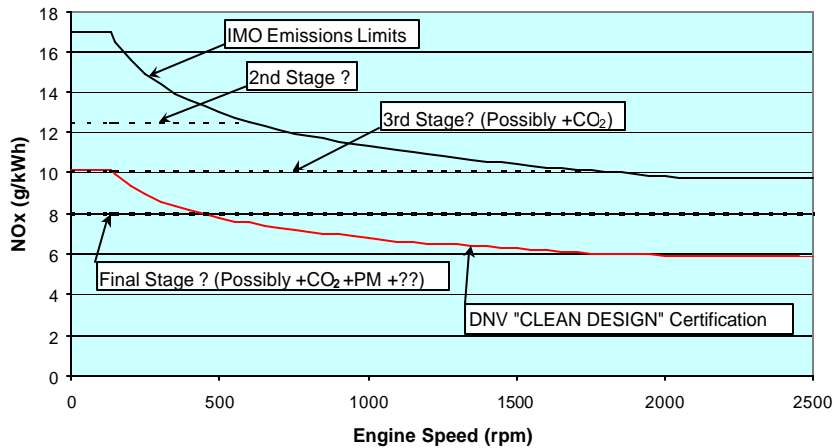


- ❑ Once Annex VI is ratified, all diesel engines >130 Kw in ships built for international shipping operation after Jan 2000 must comply
- ❑ Fuel to ISO 8217 Grade DMA, DMB or DMC. Steady state testing. Ambient 25°C, Seawater 25°C

Exhaust Emission Legislation Possible Future IMO Reduction



Possible future IMO NOx Regulation Reduction



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Marpol Annex VI SOx Limits



- ☐ Sulfur in HFO capped at 4.5%
- ☐ In SOx control area (SECA) fuel sulfur limited to 1.5% or with secondary control devices <6.0 g/Kwh emissions

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Port/Local Emissions Controls



- ❑ California, Scandinavia and Japan have decided that their air quality standards are not sufficiently protected by IMO NOx and SOx codes. They have imposed their own regulations to control marine emissions on a local basis. These include:-
 - Shutting down all engines and connecting to shore supply (is there enough shore supply available)
 - Using low sulfur fuel (possible lub oil additive issues where HFO replaced by distillate fuel)
 - Using exhaust aftertreatment
 - Vessel speed reductions in port area
- ❑ Incentives can include lower port fees

Challenges Facing Engine Builders



- ❑ NOx
 - High levels in performance (bsfc) optimized engines
- ❑ Particulate
 - High levels due to use of HFO
 - Sulfur 4.5% max
 - Asphaltenes
 - Ash
 - Residues from lube oil additives
 - Low load smoke
- ❑ Legislation and Standards
 - Proliferation of legislation
 - No common method of measurement of some key parameters, e.g. smoke

Manufacturers Responses to NOx Reduction

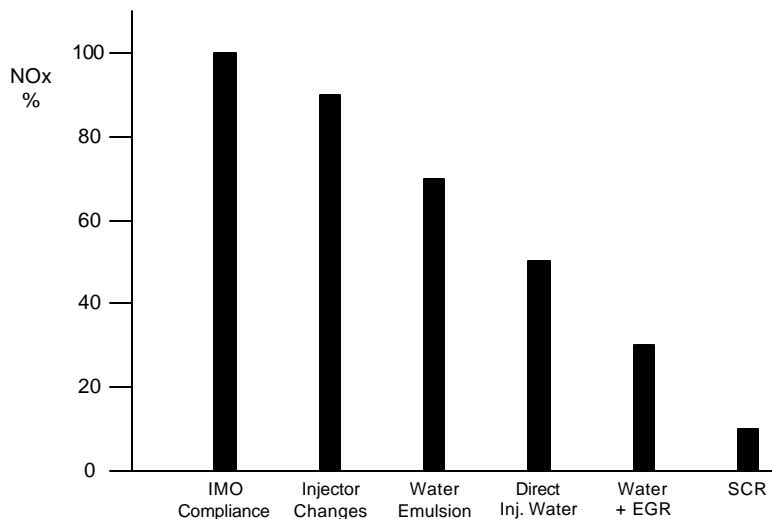


Engine	Injection timing retard + higher compression ratio + more air
Fuel Injection System	Changes to injection strategy. Rate shaping nozzle changes
Water Addition	As emulsion Direct Injection Fumigation (HAM)
EGR	not currently used due to particulate levels, but use being reviewed
Aftertreatment	SCR very effective

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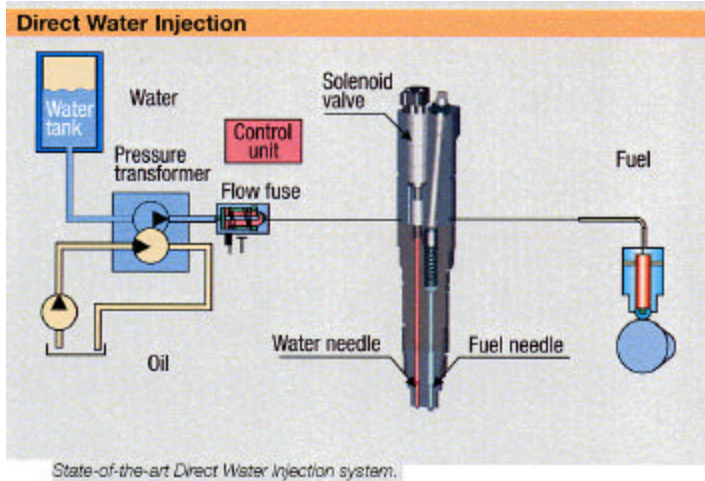
Approximate NOx Reduction For Different Control Strategies



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Direct Water Injection



Courtesy of Wärtsilä Corporation

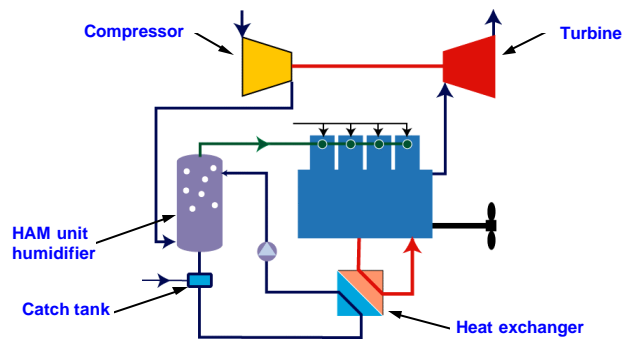
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Humidification



HAM - Principal Layout



Courtesy of MAN B&W

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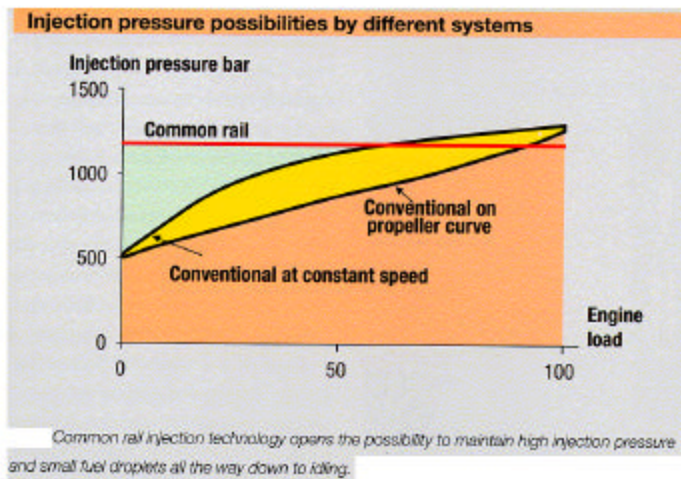
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Manufacturers Response To Particulate & Smoke Reduction



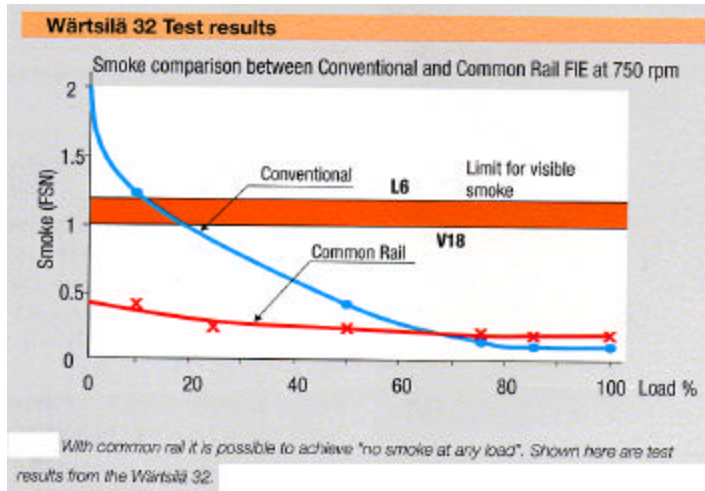
Fuel Injection System	Higher injection pressures Common Rail (CR) Nozzle changes
Air Supply System	More air at higher pressures
Base Engine	Improved combustion chamber design
Aftertreatment	Few, if any, systems in production, non-thermal plasma is showing potential for future

Injection Pressures For Different Systems



Courtesy of Wärtsilä Corporation

Smoke Values For Different Injection Systems



Courtesy of Wärtsilä Corporation

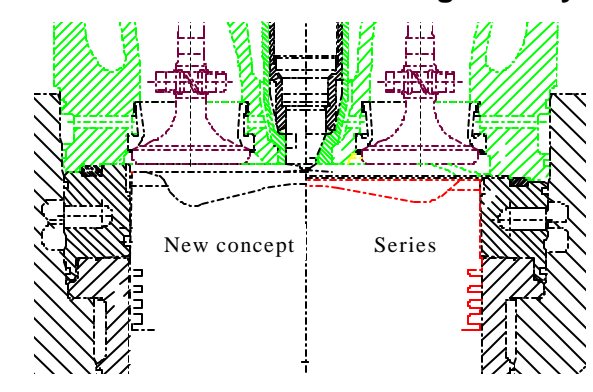
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Smoke Reduction



New cylinder head concept with new combustion chamber geometry

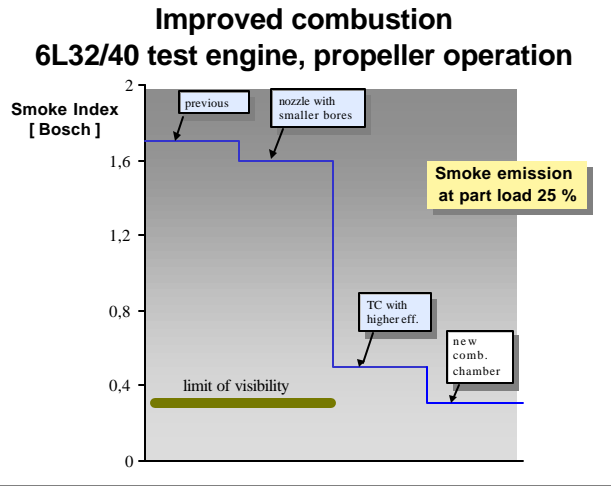


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Smoke Reduction

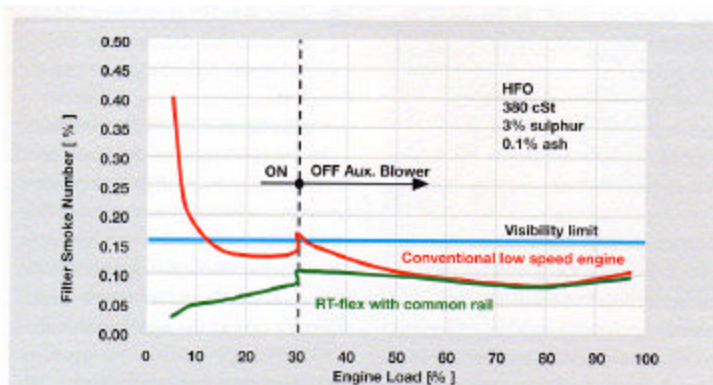


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Slow Speed Smoke Visibility For Different Injection Systems



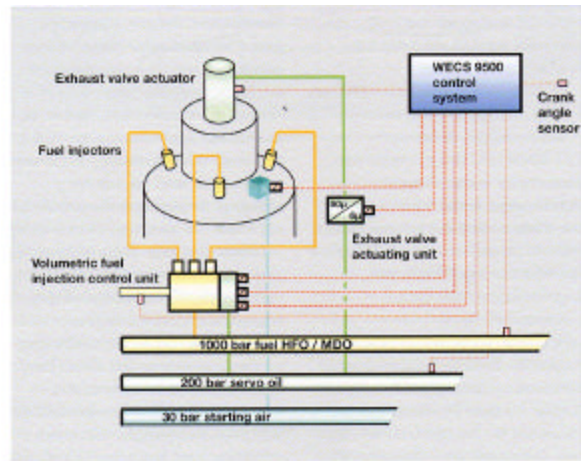
Smoke measurements from the sea trials of the Gypsum Centennial demonstrate the complete absence of visible smoke at all engine loads.

Courtesy of Wärtsilä Corporation

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Wärtsilä Common Rail System for Slow Speed Engines



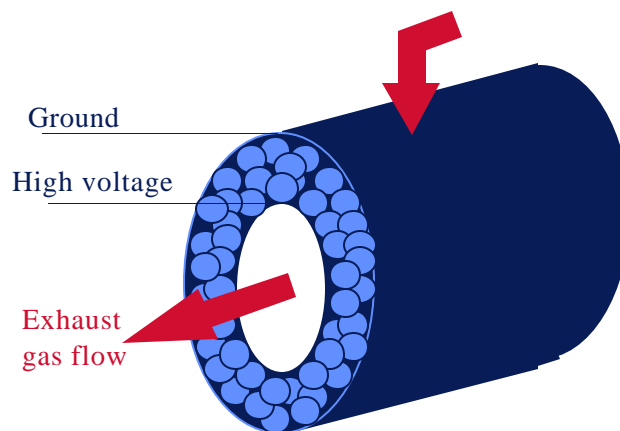
Schematic of the common-rail systems for fuel injection and exhaust valve actuation on the Suter RT-flex engine.

Courtesy of Wärtsilä Corporation

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AEA Technology's Electrocat™



Courtesy of AEA Technology

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Energy Savings



- ❑ Current thermal efficiency levels
 - Medium speed 45-50%
 - Slow speed 48 - 51.5%
- ❑ Marine installations use waste heat recovery boiler to heat process steam, further increasing efficiency
- ❑ Increases in overall engine efficiency depend on maximum cylinder pressure, turbocharger efficiency levels and fuel injection performance
- ❑ Work on reduced cooling loss combustion components can increase efficiency by up to 4%
 - Wartsila 'Hot combustion' is an example of this
 - Other similar work is ongoing
- ❑ Use of steam bottoming cycles can significantly improve efficiency but at significant cost
- ❑ Ultimately price and availability of fuel will dictate use of post-engine energy recovery devices

Alternative Fuels



- ❑ LNG carriers
 - Re-liquefaction of boil-off gas to use them in existing diesel engines is now proven technology
 - LNG fuelled oil rig supply vessel recently put into service in Norway
 - Diesel engines can be converted to run on gas, but usually have to derate by 30% or more to avoid "knock". Direct injection of gas avoids this derate but carries a significant cost and fuel consumption penalty

Conclusions



- ❑ Technologies are becoming available to significantly reduce NOx levels without an excessive fuel consumption penalty. However, their effect on the long term durability of the engines has still to be quantified
- ❑ Significant reductions in the reduction of visible smoke emissions are now possible with new technologies, but more work is needed
- ❑ Gas fuelled ships offer significant reductions in emissions levels, but their use will be restricted to coastal traffic due to fuelling restrictions
- ❑ Increases in engine thermal efficiency are possible, but the emergence of these will be driven by economics

Recommendations



- ❑ Implementation of Marpol Annex VI needs to be concluded as soon as possible
- ❑ An internationally recognized body should be tasked to come up with single exhaust smoke measuring procedure that is acceptable to engine builders, legislators and users
- ❑ Engine builders and users should be encouraged to come up with retrofit packages to improve the emissions of their existing ships